The 1998 Lincoln Model Update

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The 1998 Lincoln Model Update was conducted primarily to support the development of the 20-year Transportation Plan and included innovative concepts in transportation modeling: a Geographic Information System interface, estimation of local model parameters using the 1995 National Personal Transportation Survey (NPTS), and use of observed travel time to develop input speeds and speed-based measures of effectiveness (MOE). The GIS interface was developed to transfer data between the ARCINFO database and the transportation model network in TP+ format. This allows the transfer of roadway attributes for use in the model and model volumes, speeds, and travel times for display using the GIS maps. The 1995 NPTS was used to develop model parameters for Lincoln in lieu of a local household survey. Trip rates, lengths and peaking factors were estimated using samples within the census district including Nebraska. Results yielded significantly different model parameters than those used previously (developed from the NCHRP 187) and from national averages estimated from the NPTS. Data on travel time were observed for both off-peak and peak conditions, covering 35 percent of total roadway mileage in Lincoln. The off-peak travel time was used to develop a lookup table with representative operational input speeds by averaging speeds weighted by distance for each combination of functional type and area type. These speeds incorporate effects of signal delay, density of access points, weaving, and driver characteristics. The peak travel times were used to develop speed-based MOEs and as a validation tool for the model output speeds. Key words: Geographic Information Systems (GIS), travel forecasting, travel time and speed, performance measures.

INTRODUCTION

The 1998 Lincoln Model Update was conducted primarily to support the development of the 20-year Transportation Plan. In addition, this model supported a series of transportation planning studies, including the North 84th Street Study, the South 84th Street Study, and the S1-S2 Subarea Transportation Study. The 1998 Model Update included estimation of new model parameters using the 1995 National Personal Transportation Survey (NPTS). In addition, the 1998 Model Update was based upon observed data for travel time and speed collected during 1998. As a result, these models are substantially different than the 1995 Lincoln Models.

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This paper documents the GIS interface developed for the model network and GIS databases, the development of the travel model and validation results, and the use of the travel time and speed study data in model development and validation. This model update was a collaborative process between the consultants and city staff. The 1998 Lincoln Model was developed using a new software package, TP+ and VIPER. The 1998 Lincoln Model meets the vast majority of typical validation standards and those set forth by City staff. The results are reasonable in total and for stratification of functional class, area type, and volume group.

GIS INTERFACE

The City of Lincoln has a GIS database in ARCINFO format that is quite detailed for land parcels and roadway networks. The purpose of developing an interface between the travel model and the GIS interface was:

- To allow the GIS database to access model network attributes, such as volumes, travel times, etc., for display purposes;
- To allow the travel model to access GIS database attributes, such as road names, lengths, etc., for analytical purposes; and
- To allow continuos update of model inputs, such as counts, capacity, etc.

The methodology used was to develop a unique identifier for model network links and transfer this unique identifier to the corresponding GIS street segment. An ARCVIEW software system was developed using AVENUE to facilitate the initial development of this interface (*1*), then city staff carried out the actual development. There were a number of issues related to integration that were identified and resolved during the development and are presented in Table 1.

TABLE 1 GIS Integration Issues and Solutions

Issue	Solution
GIS and model network were not in the same coordinate system.	Model network database coordinate system was transformed using linear regression.
GIS and model network topologies were not consistent.	Tools were developed to split GIS street segments to match model network topology.
Model network directionality needed to be represented in GIS.	Directional data were transferred to the GIS street segments in directional formats.
Model network link identifiers needed to be manually transferred to GIS street segments.	Custom tools were developed to transfer model network link identifier to GIS street segments.

TRAVEL MODEL DEVELOPMENT

Travel Characteristics Data

The 1998 Lincoln Travel Model was based on travel characteristics data derived from household travel surveys conducted by the U.S. Department of Transportation in a program called the National Personal Transportation Survey (NPTS). For this study, the 1995 NPTS data were obtained and analyzed for the West North Central Region, including Nebraska, South Dakota, North Dakota, Iowa, Kansas, Minnesota, and Missouri. Household surveys were collected for more than 42,000 households nationwide and 1,478 households in the West North Central Region. These data are a valuable source of travel characteristics data for cities and states that do not conduct individual household surveys.

The NPTS data were processed for use in estimating trip generation, trip distribution, and peaking factor models for the City of Lincoln. This data processing reduced the full national household survey dataset to only those households in the West North Central region reporting weekday travel. The results of this data processing are 974 households in the sample, weighted to represent 4,738,217 households in the West North Central region and 7,498 trips in the sample, weighted to represent 42,061,090 trips in the West North Central region. The NPTS data were evaluated using the two key household characteristics variables in the Lincoln Model: dwelling unit type and area type.

Trip Generation

The weekday vehicle trips from the 1995 NPTS data were compared to the households from the same sample to estimate average weekday vehicle trip rates by household category. The household categories were developed from the Lincoln land use data for two categories of dwelling units and three categories of area types. These trip rates were calculated for the West North Central region, and the full national database and are presented in Table 2. Table 2 also presents a comparison of these trip rates to the previous 1995 Lincoln Model trip rates (*2*). A comparison of these trip rates indicates that there are significant differences in trip rates. In addition to the absolute differences, there are some important differences in the distribution of the trips by household category:

- Overall, the average trip rate is 9 percent higher in the West North Central region than in the national database. The trip rates by dwelling unit type are consistently higher for the West North Central region than for the national database, indicating that differences in trip rates are more affected by area type than by dwelling unit type. The urban trip rates are lower for the West North Central region than for the national database, while the suburban and rural trip rates are higher for the same comparison. This is probably related to the increases in household size and income for the urban category in the national database compared to the households in the West North Central region.
- The average trip rate for the West North Central region is 11 percent lower than in the 1995 Lincoln Model. All of the 1995 Lincoln Model trip rates are lower than the NPTS West North Central region trip rates except for suburban and rural single family households, which are 35 and 14 percent higher respectively. The 1995 Lincoln Model trip rates were based on ITE Trip Generation Manual (5th Edition, 1991) and then modified to account for differences in urban and suburban rates for single family households. Rural households were not separated from suburban households in this evaluation.

TABLE 2 Average Vehicle Trip Rates from the 1995 NPTS and 1995 Lincoln Model

Dwelling Unit Type	Area Type	1995 NPTS West North Central Region	1995 NPTS National	1995 Lincoln Model
Single Family & Duplex	Urban	8.92	10.12	7.65
	Suburban	9.99	8.20	11.40
	Rural	8.43	7.38	11.40
	Subtotal	9.17	8.72	
Multi-Family	Urban	7.32	7.25	6.50
	Suburban	7.70	6.28	6.50
	Rural	7.48	6.45	6.50
	Subtotal	7.46	6.85	
Total Households	Urban	8.55	8.96	
	Suburban	9.64	7.76	
	Rural	8.34	7.17	
	Subtotal	8.88	8.16	10.0

The 1995 NPTS data was further evaluated by trip purpose in order to expand the trip purposes in the 1998 Model. The 1995 Lincoln Model had three trip purposes: home-based work, home-based other, and non-home-based. One of the advantages of using the 1995 NPTS survey data instead of the NCHRP 187 manual for deriving trip rates is that there are more choices of trip purpose categories than the three reported in the NCHRP 187 manual. These additional trip purposes can have significant effects on future forecasts of land development for specific uses such as shopping or recreation that would not be accounted for otherwise. There are also differences in trip purposes that are accounted for by using the more updated data source (1995 data instead of the 1978 data used in NCHRP) which probably accounts for the significant increase in non-home-based travel (see Table 3).

TABLE 3 Trip Purposes for the 1999 Lincoln Model Compared to the 1995 Lincoln Model

Trip Purpose	1998 Lincoln Model (percent of total trips)	1995 Lincoln Model (percent of total trips)
Data Source	1995 NPTS for West North Central Region	NCHRP 187 Quick Response Manual (1978)
Home-Based Work	24	25
Home-Based Shop	10	
Home-Based Recreational	13	66
Home-Based Other	19	
Non-Home-Based	34	9

Trip Distribution

Trip lengths are defined by the average trip length as well as the trip length frequency distribution for each trip purpose. Observed data on trip lengths were developed from the 1995 NPTS data. Friction factors were developed using a gamma function to estimate the friction factors and application of the trip distribution model to identify the "best-fit" for the average trip length and trip length frequency distributions. The gamma functions used to develop these functions used the following equation:

$$\text{Alpha} * (I^{\text{Beta}} * e^{I * \text{Gamma}})$$

Where:

Alpha, Beta and Gamma are coefficients, and

I is the impedance, or trip length in minutes.

A comparison of average trip lengths by trip purpose is provided in Table 4. The 1995 NPTS average trip lengths were used to estimate friction factors for use in the 1998 Lincoln Model, but these trip lengths produced traffic volumes considerably higher than traffic counts in Lincoln. This would indicate the average trip lengths are slightly lower in Lincoln than in other areas around the West North Central region. Two other cities and the previous 1995 Lincoln Model trip lengths are provided for comparison. The 1995 Lincoln Model used friction factors provided by the Federal Highway Administration that were established in the 1990 model development effort *(3)*. The home-based work and non-home-based trip lengths are the most similar, with the home-based shopping and recreational trip lengths being the most different from the 1995 Lincoln Model, confirming the benefits of incorporating separate trip purposes.

TABLE 4 Average Trip Lengths for the 1998 Lincoln Model in Minutes

Trip Purpose	1998 Model	1995 NPTS	Reno, NV	Tucson, AZ	1995 Model
Home-Based Work	12.4	12.9	11.2	17.7	12.8
Home-Based Shop	9.4	10.1	8.6	10.3	
Home-Based Recreational	9.9	11.1			
Home-Based Other	10.4	11.2	10.4	12.3	11.4
Non-Home-Based	10.6	11.9	8.1	11.9	10.5

Screenlines are usually indicative of whether the trip distribution is reasonable because they will identify patterns of east-west or north-south movements. There are eight screenlines in the Lincoln Model. Table 5 presents the results of the screenlines compared to the results for these same screenlines in the 1995 Lincoln Model. In all but three cases, the screenlines meet the +/- 5 percent goal. In many cases, the 1998 Model has better results on the screenlines than the 1995 Model. The results of the screenline analysis indicate that the pattern of trip movements is reasonable compared to observed values.

TABLE 5 1998 Model Validation of Screenlines

Screenline		Percent Difference	
		1998 Model	1995 Model
1	56th Street	-3.9%	1.6%
2	27th Street	1.9%	-2.2%
3	A Street	8.4%	8.5%
4	Adams Street	2.3%	-6.4%
5	Havelock Ave	-3.6%	-7.6%
6	Old Cheney Rd	-5.9%	-2.7%
7	84th Street	-2.3%	-19.5%
8	Coddington Ave	7.6%	-10.1%
		Goal for Screenlines is +/-5%	
Total		1.1%	-1.5%

Trip Assignment

Trip assignment is typically validated by comparing traffic counts to model volumes for different market segments and to summarize system-wide variables. The summary of system-wide statistics is presented in Table 6 and reflects strong correlation between volumes, speeds, and travel times for the 1998 Model Update.

TABLE 6 Summary of System-Wide Statistics for 1998 Model

	1998 Model	1998 Counts	Percent Difference
Vehicle Miles Traveled	2,494,501	2,523,139	-1.1%
Total Vehicle Hours Traveled	93,451	94,590	-1.2%
Free Flow Hours Traveled	83,498	84,457	-1.1%
\Delay Hours	9,953	10,134	-1.8%
Average Congested Speed (MPH)	27.86	26.67	4.4%
Average Speed (MPH)	29.87	29.87	—

The summaries of traffic counts and modeled volumes by functional class are presented in Table 7. These classifications also have established goals of percent deviation that are presented in the table. All of the classifications meet the goals for percent deviation. These results are also compared to the 1995 Lincoln Model in Table 7, but very few differences exist. This may be due to the fact that the 1995 Model employed facility-specific data on speeds and capacities that were adjusted to achieve the best fit to the traffic count data, where the 1998 Lincoln Model relied on categorical speeds and validation of the speeds to observed data. The 1998 Lincoln Model did separate divided highways from the principal arterial category and gravel roads from the collector category of roads.

TABLE 7 1998 Model Validation by Functional Classification

Functional Classification	Percent Difference		Goal
	1998 Model	1995 Model	
Freeways & Ramps	4.3%	-3.9%	5.0%
Divided Highway	1.8%		10.0%
Principal Arterial	1.8%	3.8%	10.0%
Minor Arterial	-1.9%	-0.4%	15.0%
Collectors	23.4%	-3.6%	25.0%
Gravel Roads	-24.4%		N/A
Total	1.3%	1.2%	5.0%

TRAVEL TIME AND SPEED STUDY

Travel time and speed is a critical input in the Lincoln travel model and is also used to validate the travel model output. In recent research, travel models give more realistic results with operational speeds as inputs compared to the more traditional posted speeds. Operational speeds account for effects of signals, density of access points, and driver characteristics. Recent research and practice has also shown that speed-based performance measures are better indicators of system-wide performance than traditional level-of-service based performance measures. Speed provides a direct connection between system-wide transportation planning and project implementation. Speed is also an easier concept to understand by the general public and easier to measure in the field. As a result, the Mayor of the City of Lincoln's Congestion Management Task Force (CMTF) has recommended speed-based performance measures be used to identify and select future transportation improvement projects.

Data Collection

A data collection effort was undertaken (*4*) to obtain current speed data for the planning process. Representative corridors were selected in the sample of roads to be surveyed and speeds were observed with test runs during the midday and PM peak periods. These data were combined with travel time and speed data collected in a previous study for the City of Lincoln. A minimum of three runs (or sample size) was required for a confidence level of 95%, with a permitted error of ±5.0 MPH, assuming a range of 10 MPH in the average running speed. The sample included 146 miles of roadways, which constitutes about 35 percent of total roadway mileage in the Lincoln area. This sample size was considered statistically adequate to represent all functional classes of Lincoln area roadways. Speeds were analyzed by area type and functional classification to evaluate the reasonableness for each category. Table 8 summarizes the total mileage in the Lincoln area and the mileage included in the sample. Table 9 summarizes the number of link segments where speed and travel time data were collected by area type and functional classification.

TABLE 8 Miles of Roadway by Functional Class (within the Lincoln Cordon Area)

Functional Class	Total Roadway Mileage	Model	Sample Mileage
Urban/Rural Interstate	28.9	Freeways	11.5
Urban/Rural Principle Arterial	95.3	Principle Arterials	46
Urban/Rural Minor Arterial	110.9	Minor Arterials	68.5
Urban Collector	71.7	Collectors	11
Rural Major Collector (State)	3.5		
Rural Major Collector (County)	101.4	Divided Highways	9
Rural Minor Collector	11.8		
Total	423.5	Total	146

TABLE 9 Count of Link Segments included in Speed Data Collection

Functional Class	Area Type				
	CBD	Urban	Suburban	Rural	Total
Freeway	-	4	45	4	53
Divided Highway	-	11	25	5	41
Principal Arterial	46	231	167	7	451
Minor Arterial	12	353	236	6	607
Collector	-	35	74	3	112
Total	58	634	547	25	1,264

Analysis

The analysis of speeds collected in Lincoln began with a comparison of the average speeds—for each functional class and area type category for the original 1995 Lincoln Model,—the midday speeds, and the PM peak speeds. These results were refined in cases where sample size for a category were too small to be reliable, and these speeds can be identified by the even numbers where the actual speeds from the speed study are identified by exact numbers (with one decimal place).

The speeds used in the 1998 Model were compared to the average weighted speeds contained in the 1995 Lincoln Model for the same functional class and area type categories in Table 10. The speeds in the 1995 Model were not used according to these functional class and area type categories, so this comparison is for information only. The speeds used in the 1995 Model were coded specifically for each link based on a combination of observed data and engineering judgment.

The comparison of average speeds resulted in the following conclusions:

· The average midday speeds (33.0 miles per hour) are almost the same as the 1995 original speeds (31.8 miles per hour) overall, but there are significant differences for freeways, rural arterials, collectors, and minor arterials in the Central Business District (CBD).

TABLE 10 Recommended Speeds for the 1998 Model Update

Functional Class	CBD	Urban	Suburban	Rural
Freeways	50.0	50.0	57.6	60.0
1995 Model Speeds		49	45	49
Freeway Ramps	30.0	30.0	30.0	30.0
Divided Highways	42.0	42.0	45.0	48.0
Principal Arterials	22.7	29.1	36.2	44.0
1995 Model Speeds	21	29	37	42
Minor Arterials	22.0	25.5	29.3	36.0
1995 Model Speeds	21	27	30	31
Collectors	20.0	24.9	29.7	34.0
1995 Model Speeds		26	31	31
Gravel Roads	31.0	31.0	31.0	31.0

- Peak speeds (31.1 miles per hour) are, as expected, lower than midday speeds overall but freeways actually show higher peak speeds than midday speeds (although this is probably within the margin of error for the number of samples collected).

The average speeds using the highest of the midday and PM peak speeds (34.4 miles per hour) are 1.4 mph faster than the average midday speeds. There are 381 links out of the 1,264 total links (30 percent) that have a midday speed lower than PM peak speed. Of these, 16 percent (197 links) are more than ten percent lower than PM peak speeds. Recommended speeds for input to the 1998 Lincoln Travel Model were derived from the average weighted midday speeds, with minor adjustments, as follows:

- The only freeway classification with a statistically significant sample is suburban freeways at 57.6 mph. Other freeway segments are set according to judgement and were validated using model volumes and traffic counts.
- Divided highways also have low sample size for urban and rural classifications and are set based on the validation of model volumes and traffic counts for these facilities. Suburban divided highways are set according to observed values.
- CBD minor arterials also suffer from low sample size and are considered not statistically different than urban minor arterials. As a result, CBD minor arterials are set at 22 mph rather than the 28.2 mph estimated for this category.
- CBD collectors are set at 20 mph because there were no CBD collectors in the sample.

All classifications of rural roads have insignificant sample sizes and are difficult to specify as a result. Further data collection of rural facilities is recommended. Rural divided highways and principal arterials are set at observed values because these seem reasonable. Rural freeways, minor arterials, and collectors are set at 60 mph, 40 mph, and 40 mph, respectively, based on judgement.

CONCLUSION

The Lincoln Transportation Studies project was to improve the travel demand forecasting model with specific planning purposes in mind. To that end, the GIS interface, model improvements, speed, and travel time study components of the project were all designed to address these specific planning purposes. The interface with GIS provides superior display capabilities and more accurate data processing for the travel model and facilitates the use of these data from one system to the other. The land use data used in the model were always derived from the GIS land-based parcel database, but the roadway system was improved by using the more accurate estimates of distance contained in the GIS.

The travel model improvements were designed to use more current travel characteristics data (from the 1995 NPTS household survey) and to provide more detail in terms of trip purpose, area type, and functional classification for improved accuracy of the results. This paper compares the results of these model improvements compared to observed data sources and the previous 1995 Lincoln Model to demonstrate the improved performance of the model. The model was subsequently used for the S1-S2 Subarea Transportation Study (*5*), the North 84th Street Subarea Study (*6*), and the South 84th Street Subarea Study (*yet to be published*), which confirmed the reasonableness and reliability of the model improvements.

Finally, the usefulness of the model has improved with the validation of speeds and travel times and the use of observed operational speeds as input to the travel model. Transportation alternatives can be assessed in real-world terms (minutes of travel time or speed) rather than traffic engineer lingo (level-of-service categories) to evaluate and select transportation projects. In addition, transportation planners can monitor and update these data with ongoing before and after studies for implemented projects.

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